

Day-night asymmetry of the Earth-ionosphere cavity traced by Schumann resonance observations

M. Neska (1) , G. Satori (2)

(1) Institute of Geophysics of PAS, Poland

(2) Geodetic and Geophysical Research Institute of HAS, Hungary

nemar@igf.edu.pl (1), satori@ggki.hu (2)

In terms of electromagnetics, both the solid Earth and the ionosphere are conductors and the atmosphere in-between is a resistor (fig.1). Hence electromagnetic waves generated during thunderstorms propagate through the atmosphere and are reflected by the Earth's surface and by the lower ionosphere. Thereby the Earth-ionosphere cavity forms a waveguide for the spectrum of lightning discharges. Due to its geometry, this cavity has certain eigenfrequencies, i.e. the amplitudes of waves at these frequencies are preserved throughout the globe, whereas others are attenuated faster with distance from the lightning stroke. These eigenfrequencies are called Schumann resonances (SR) after their discoverer. The first three SR modes amount to 8, 14, and 20 Hz, only they go into the present study.

According to the SR theory, the SR intensities at a given location depend on the lightning source parameters, on the cavity properties, and on the source-observer angular distance. All these parameters have temporal variations. So the worldwide thunderstorm activity, which is concentrated above the three landmasses situated

in the tropics (Africa, the Americas, and Asia/maritime continent, see fig.2), depends in its strength and latitude on the seasons, on meteorological conditions, and last not least, has a highly visible diurnal cycle beginning in general at local noon and lasting till local nightfall.

There is also a fundamental diurnal cycle in the

electrical properties of the ionosphere above a given observation point on the Earth's surface, the so-called day-night asymmetry of the Earth-ionosphere cavity. The conductivity of the lower part of the ionosphere (D-layer) is due to the sun's radiation, which keeps the electrons and ions of the gas molecules apart from each

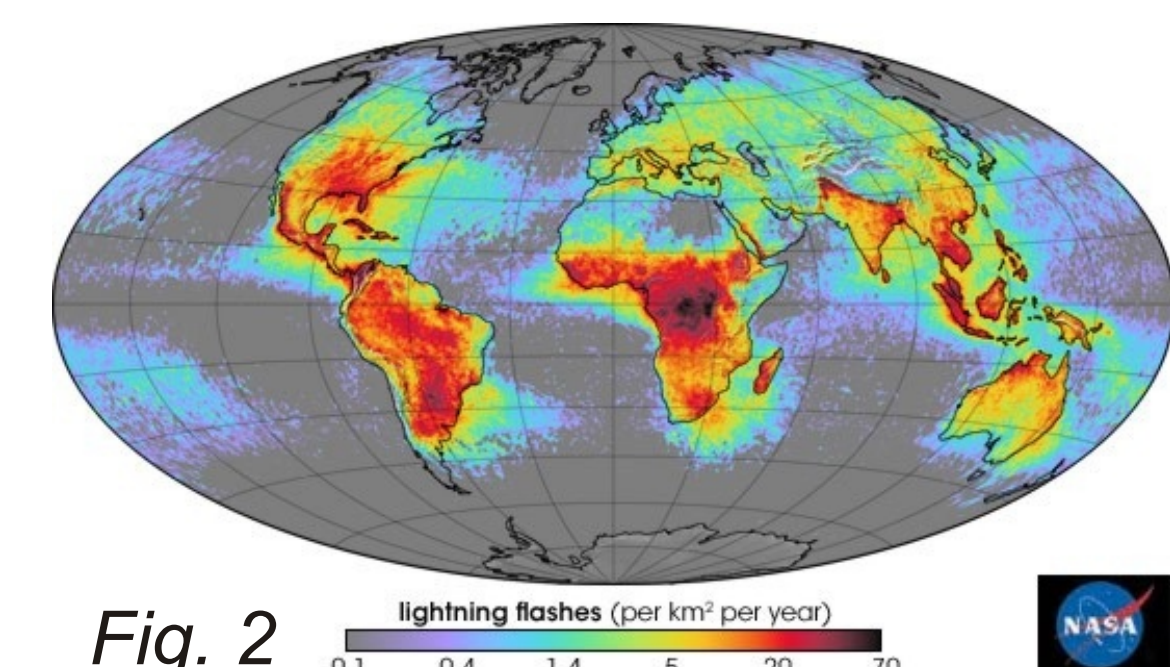


Fig. 2

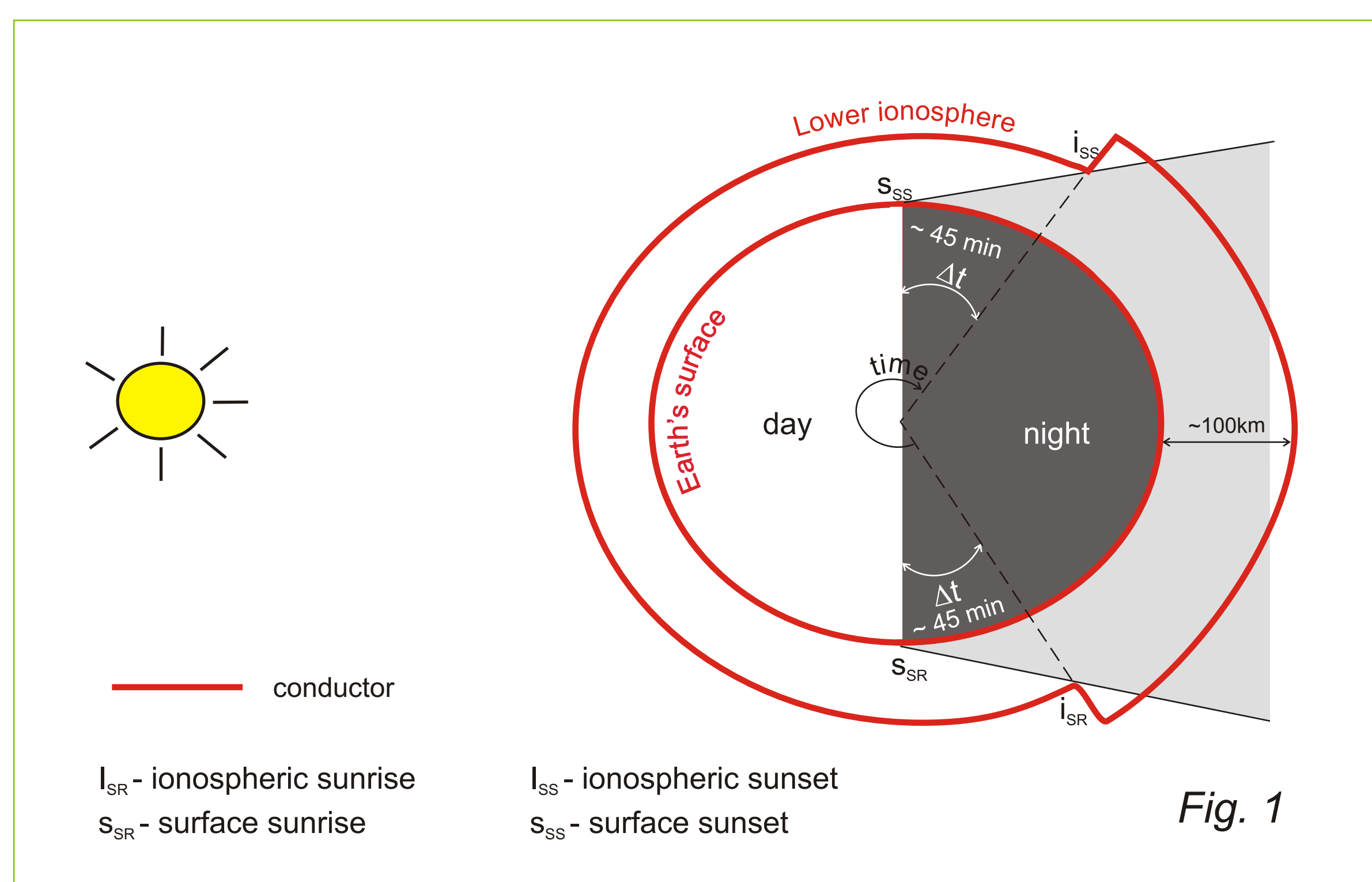


Fig. 1

other. When getting into the globe's shadow at night, this ionized gas of the D-layer undergoes neutralization and the conductive properties of the wave-guide retreat to greater height (fig.1). This leads to a smaller energy flux density of the passing-through electromagnetic waves and can be observed in form of down-scaled SR intensities at observation points beneath the retreated ionosphere at the night side of the Earth.

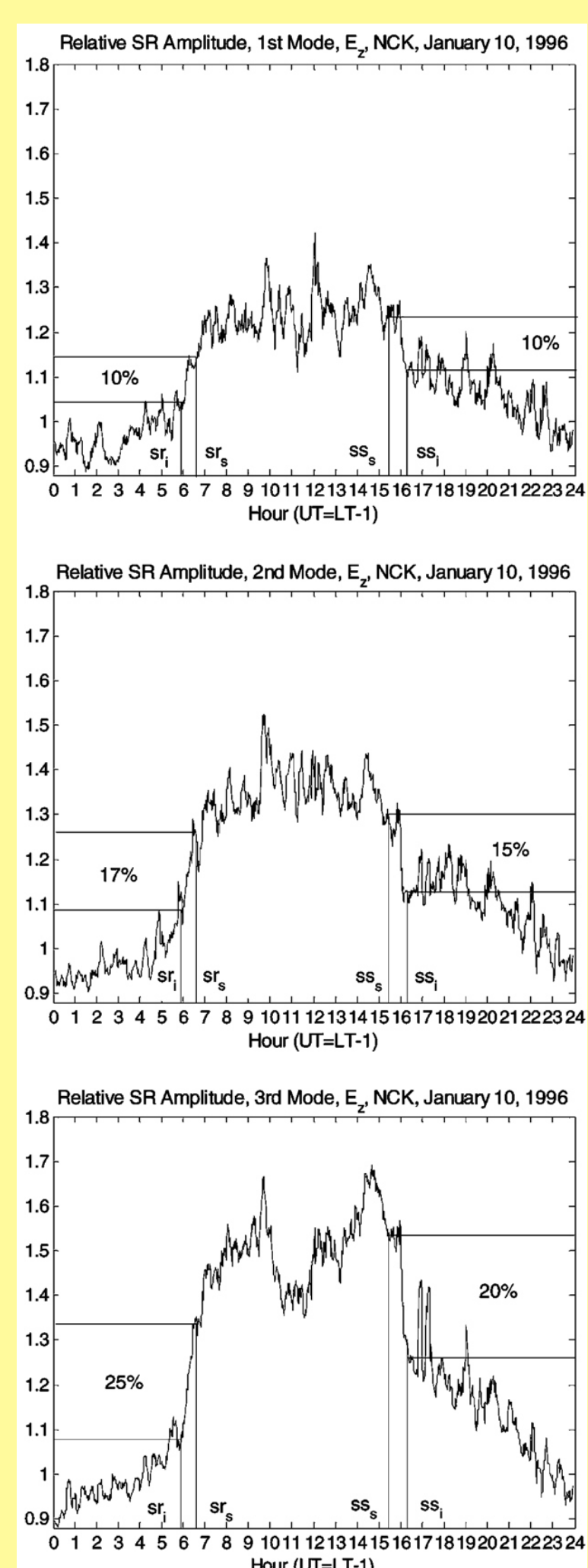


Fig. 4

The aim of this presentation is to show that it is possible and necessary to distinguish between the "thunderstorm activity" and the "ionospheric" diurnal cycles of SR intensity by means of high time resolution SR records.

These records owe their availability to geomagnetic observatories conducting a SR monitoring. Such a measurement comprehends the magnetic North (H_N), magnetic East (H_E), and vertical electric (E_z) components sampled continuously with 100 Hz. Records from Nagycenk (NCK, Hungary) and Hornsund (HRN, Polish Polar Station on Spitsbergen Island) observatories (fig.3) went into this study. Data were processed in a way yielding spectral amplitudes in a quasi-minute time resolution. This is a high resolution compared to analogous studies, but necessary to trace the abrupt changes unveiled in the following.

Fig.4 shows the relative SR amplitude variations in E_z observed for the first three SR modes in

NCK on 10 January 1996. On the omnipresent fluctuations, there is superimposed a steep increase of amplitudes between the hours of ionospheric sunrise (marked by a vertical line s_r) and local surface sunrise (s_s) and a similar decrease between local sunset (s_{ss}) and ionospheric sunset (s_{sr}). Ionospheric sunrise means the moment when the lower ionosphere in about 100 km height above the observation point leaves the globe's shadow due to the diurnal rotation. This event takes place ca. 45 minutes before sunrise at surface (fig.1), the ionization process is turned on, and the SR intensity rises. The process is happening the opposite way when the ionosphere above the observation point ingresses into the Earth's shadow (so-called ionospheric sunset) some 45 minutes after local surface sunset. This diurnal increasing and decreasing of SR amplitudes starts very exactly ("clock-like") in the described 45 minutes interval throughout the observations.

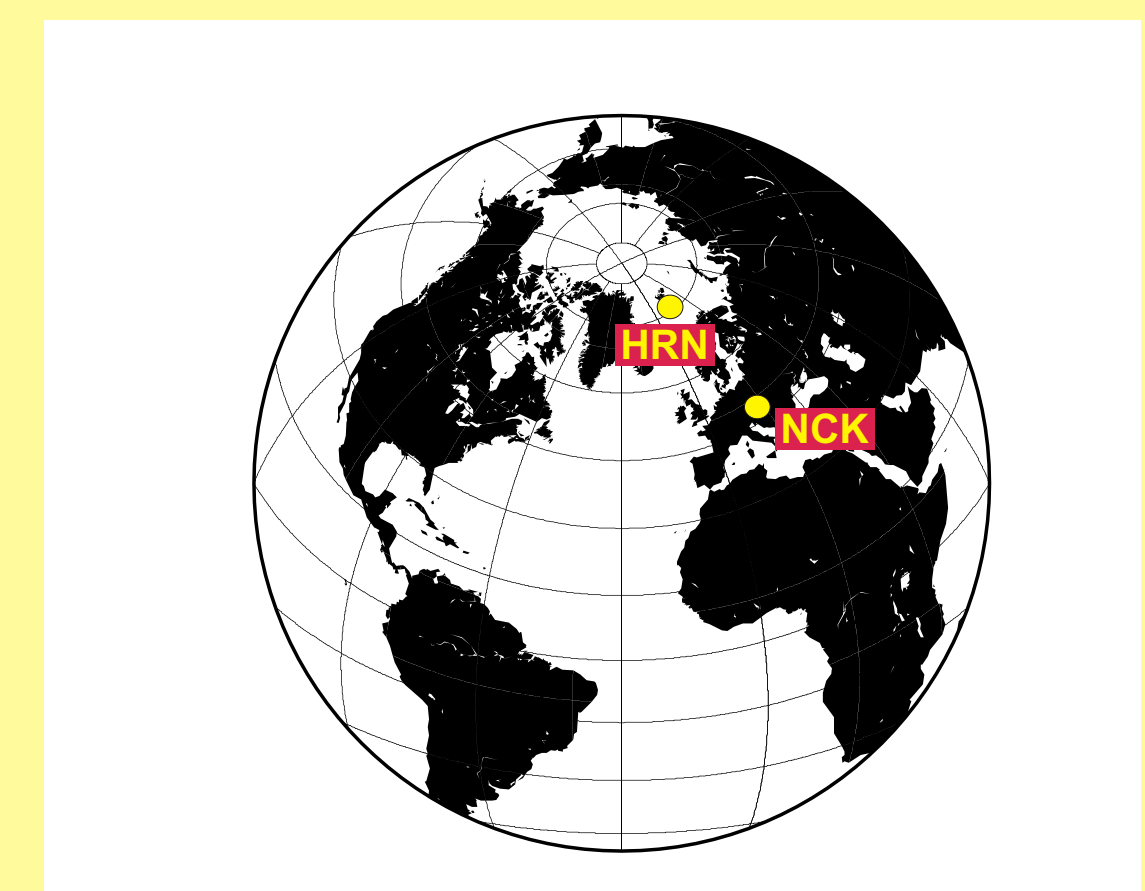


Fig. 3

The difference between "day" and "night" amplitudes increases with increasing mode number, i.e. the high-frequency SR modes show a greater contrast (20-25% at 20 Hz, lower panel in fig.4) than the low-frequency ones (10% at 8 Hz, upper panel in fig.4).

Furthermore, it is worthwhile mentioning that during the steepest phase of the amplitude variations, the omnipresent fluctuations decrease for reasons currently unknown.

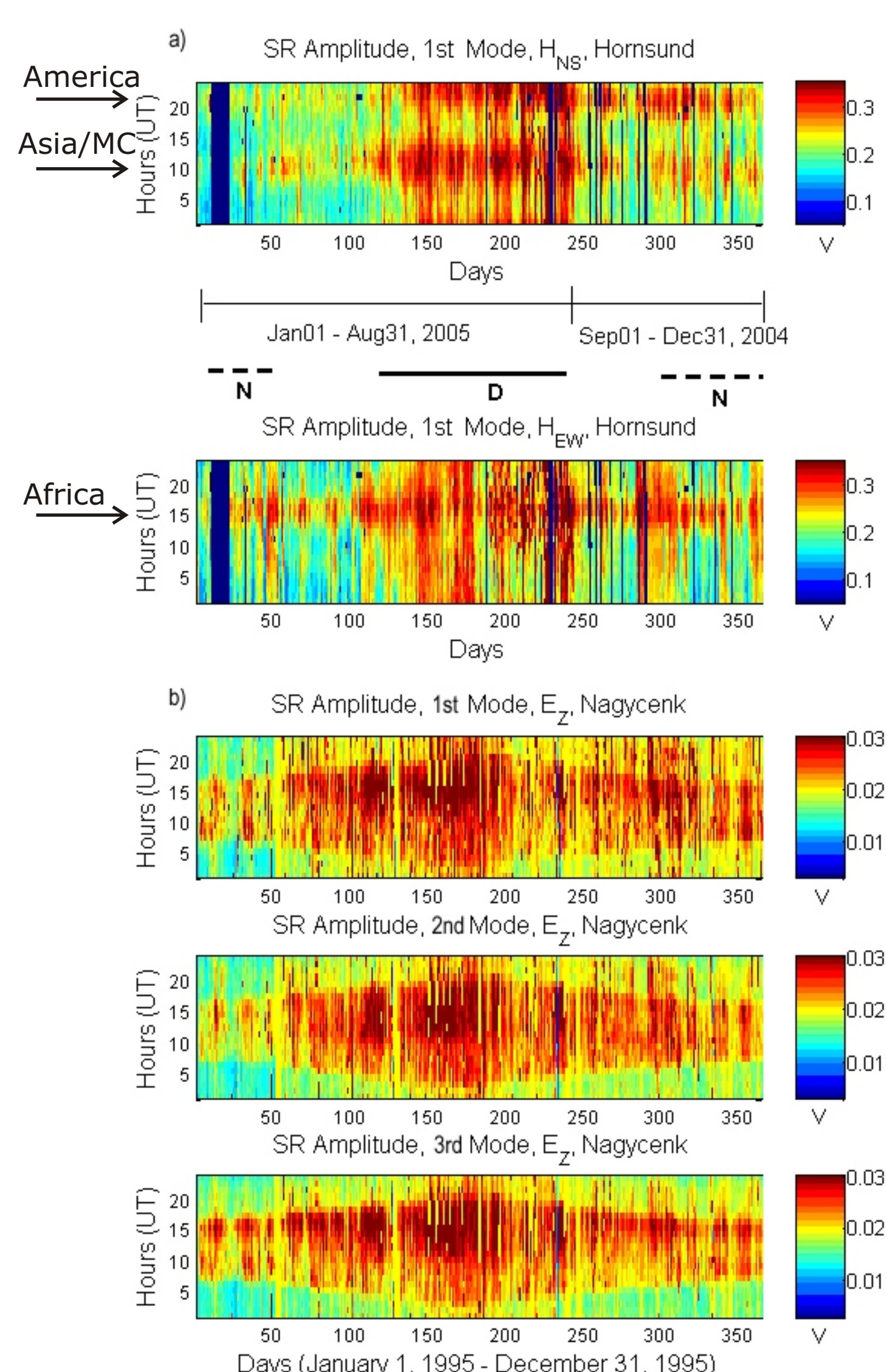


Fig. 5

In order to understand in which extent the day-night asymmetry influences the diurnal SR amplitude variations it is very instructive to consider SR data from HRN. Spitsbergen is situated beyond the Arctic Circle and therefore lacks diurnal sunrise and sunset during most time of the year.

Fig.5 presents diurnal SR amplitude variations lined up for one complete year showing (a) the horizontal magnetic field components H_N and H_E for the first mode at HRN and (b) the vertical electric field component E_z for first three SR modes at NCK. It has to be mentioned here that E_z is responsive to all three centers of thunderstorm activity, but is of somewhat lower data quality in HRN, so that both magnetic components from there had to be regarded instead. H_N is responsive to lightning discharges in Asia/ maritime continent and the Americas and H_E to those from Africa. The NCK annual overview exhibits a regular eye-shaped pattern coming out the clearer the higher the SR mode number is. This pattern is created by the day-night variation of SR amplitudes described above in connection with the varying day length through the year. In contrast, the main pattern emerging from the HRN annual overview consists of horizontal lines of enhanced amplitudes correlated to the times when thunderstorm activity in the three centers Africa, Asia/maritime continent, and America is maximum. Looking very attentively at the NCK picture it may be possible to identify the African and Asian/MC lines

there as well, but the American one is missing. It has to be noted here that it is night in NCK when the American thunderstorm center is active. Since the conditions concerning source-observer angular distance to the three centers are comparable for HRN and NCK, the weak signatures of the thunderstorm centers in NCK must be due to the preponderance of the signature from the day-night asymmetry in the lower ionosphere above NCK.

Of course there are transition seasons with diurnal day-night change on Spitsbergen, too. For the following consideration, we looked at H_E component at HRN that has its diurnal maximum at around 16:00 LT connected to African lightning activity. Comparing relative diurnal (i.e. normalized to local midnight hour when amplitudes are minimum) SR intensity variations of these periods to those from periods of polar night and polar day, we obtained a higher relative importance of the "African" maximum during transition periods because of the additional day-night variation. This calculation was done for two-week periods in January 2005 (full-night conditions), May 2005 (full-day conditions), September 2004, and March 2005 (both with day-night transitions) for the first three SR modes and is imaged in fig.6.

Concluding, we can state that it is possible to trace the day-night asymmetry of the Earth-ionosphere cavity in SR records and to distinguish its signature clearly from source-related SR intensity variations. This is necessary to use either of them further.

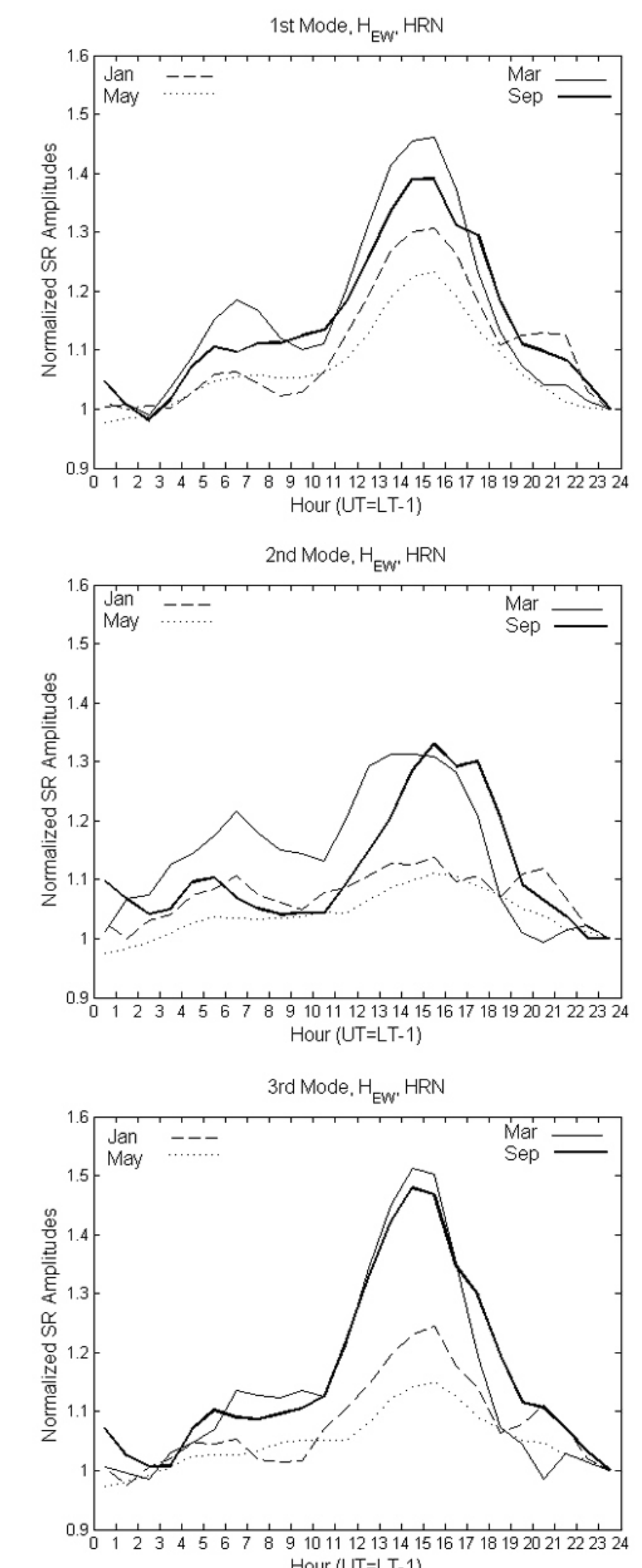


Fig. 6